MERCURY LIFE SUPPORT SYSTEMS

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INTRODUCTION

This paper defines the design objectives for the Mercury environmental control system, describes the system components, outlines system instrumentation and controls, and presents the concepts of operation for orbital flight.

The primary purpose of Project Mercury is to place a man in orbit approximately 100 miles above the earth and return him safely. Space capsules are presently being developed for ballistic launch by Redstone missiles and orbital launch by Atlas missiles. The capsule when placed in orbit will circle the earth in approximately 90 minutes. The first orbital flights will consist of 3 orbits with a total flight time of $4\frac{1}{2}$ hours. Reentry will be accomplished by firing retrorockets to decrease the capsule velocity and allow the earth's gravitational force to bring the capsule into the earth's atmosphere. The capsule will be recovered by a parachute system and impact will occur in the Atlantic ocean.

To support a man in these flights a closed-type environmental control system has been developed by McDonnell Aircraft Corporation, the capsule prime contractor, and AiResearch Manufacturing Division of the Garrett Corporation, the system subcontractor.

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SYSTEM DESIGN PARAMETERS

The primary function of the environmental control system is to provide a liveable gaseous environment to the astronaut. This requires control of the gaseous composition, temperature, and pressure. The secondary function of the system is to provide adequate cooling for the electronic equipment aboard the capsule. The system has been designed to the following specific requirements:

(a) To provide metabolic oxygen, pressurization, and ventilation in the pressure suit and cabin for a minimum of 28 flight hours

(b) To provide selectable cabin temperature between 50° and 80° F in the orbital phase with a maximum of 200° F in the launch and reentry phases

(c) To remove carbon dioxide and water produced by the astronaut

(d) To provide comfortable humidity/temperature combinations within the pressure suit during all phases of flight

(e) To operate in weightless or high acceleration conditions

DESCRIPTION OF SYSTEM

Figure 1 shows the environmental control system capsule installation. This system maintains the capsule at 5 psi with an oxygen atmosphere. The astronaut wears a full pressure suit which serves as a backup to the cabin pressurization system and provides body ventilation. The system is designed to automatically control the environmental conditions within the suit and cabin during all phases of flight. The system also provides manual controls to enable system operation in the event of automatic controls malfunction. The environmental control system can be considered as two subsystems; the cabin system and the pressure suit control system. Both of these systems operate simultaneously in normal operation from common oxygen, coolant water, and electrical supplies.

Common Supplies

Oxygen is stored in two spherical 7,500-psi containers (fig. 2). Each contains 4 pounds of oxygen which is sufficient for 26 flight hours assuming a consumption rate of 500 cc/min and a maximum cabin leakage rate of 300 cc/min. The containers are equipped with a filler valve for ground servicing a shutoff valve, and a pressure transducer to provide data on the supply pressures. Both containers are equipped with pressure reducers to reduce the primary supply pressure to 100 psi and the emergency supply to 80 psi. The two containers are coupled such that upon depletion of the primary supply the emergency supply is automatically actuated.

A coolant water tank (fig. 3) designed to operate in weightless flight supplies water under pressure to cabin and pressure suit control system heat exchangers. The tank is fitted with an elastic membrane and oxygen is admitted to one side of the membrane to force water from the tank into the heat exchangers. Control valves are provided on the capsule consoles to meter water flow into the heat exchangers.

Electrical power is supplied as 115-volt 400-cycle a.c. current to drive system blower motors and 28-volt d.c. current is supplied to operate various solenoid valves and system instruments.

Pressure Suit Control System

The pressure suit control system (fig. 4) provides breathing oxygen, maintains pressurization, removes metabolic byproducts, and controls ventilation temperatures.

The pressure suit is coupled into the system by an inlet connection at the pressure suit torso and an exit connection at the helmet. A compressor circulates a 100-percent oxygen gas stream into the suit where carbon dioxide, water vapors, and body odors are picked up. The gas passes through a solids trap to remove particulate matter and is passed on into a chemical canister to remove odor and carbon dioxide. The gas stream then passes through a heat exchanger where the gas is cooled to approximately 45° F. The water vapors condense into water droplets and are carried suspended in the gas stream into a water separator. The purified oxygen stream then passes into the suit.

Pressurization in the pressure suit control system is maintained by a demand type pressure suit regulator. In normal operation this regulator meters oxygen into the circuit to maintain the suit at nominal cabin pressure. In the event of a cabin decompression the regulator senses the loss in pressure and maintains the pressure suit at 4.6 psi.

An additional emergency mode of operation is provided in the pressure suit control system by an emergency rate valve. In the event that the normal suit pressurization system fails, the emergency rate valve senses this emergency and directs an oxygen flow of 0.05 lb/min through the pressure suit and out an exhaust port of the pressure suit regulator into the cabin. When this mode of operation is used the pressure suit control system compressor is automatically turned off and a system shutoff valve closed. The emergency rate valve may also be manually actuated by a control handle on the capsule console. This serves as a backup to the automatic actuation and provides a manual mode of operation should a pressure suit control system failure occur which could not be automatically sensed. For example, failure of the carbon-dioxide absorber and subsequent buildup of carbon dioxide would not automatically actuate the emergency rate mode of operation.

A research and development model of the full pressure suit to be used in project Mercury is shown by figure 5. This suit is being developed by NASA, the B. F. Goodrich Company, and the U. S. Navy. The single-piece suit incorporates a ventilation system to distribute the ventilation gas throughout the body. A bio-sensor connector is provided on the suit torso to bring bio-sensor leads out of the suit. The helmet incorporates communication equipment and two microphones are provided for redundancy. A pneumatic-type visor seal is provided and is actuated by a separate oxygen source.

The major components of the suit circuit are shown in figures 6 through 10.

The solids trap (fig. 6) has been designed to remove solid matter which may be dispelled into the pressure suit control system. A flapper-type valve is provided to allow bypass flow through the trap should the filter become clogged.

The pressure suit control system compressor is a centrifugal compressor which develops a flow of 10 cfm with a pressure head of 10 inches of water. Two compressors are provided in the pressure suit control system for redundancy. Should the primary blower fail, a pressure switch senses the loss of pressure across the blower and automatically turns off the primary blower and starts the backup blower.

The odor and carbon-dioxide canister (fig. 8) is made up of a 1-pound bed of activated charcoal and two 2.6-pound beds of lithium hydroxide. Two lithium hydroxide beds are provided to prevent channelling or carbon dioxide bypass. A filter is installed on the outlet side of the canister to prevent lithium hydroxide dust from passing into the system.

The pressure suit control system heat exchanger (fig. 9) is a water evaporator type rated at 1,000 Btu/hr. The pressure suit control system stream makes a single pass through the heat exchanger and exits at approximately 45° F. Water is fed from the coolant water tank onto a fiber pad and into capillary-like tubes of the heat exchanger. The water removes heat from the gas stream and evaporates. The water vapors then make a second pass through the heat exchanger where heat is removed from the inlet gas superheating the water vapors. The superheated water vapors are then passed overboard. The purpose of this second pass is to assure superheating of the water vapors to prevent icing in the overboard vent line. The overboard vent line is instrumented with a temperature switch which actuates a warning light when the water vapor temperature drops below 50° F. This gives a visual indication of excessive water flow into the heat exchanger. Prelaunch ground cooling is provided by the heat exchanger bypassing Freon-114 through a capsule umbilical connection into the water side of the heat exchanger.

The water separator (fig. 10) consists of a vinyl sponge which absorbs the condensed water droplets. The sponge is squeezed by an oxygen driven piston every 30 minutes to force the condensate water into a storage tank. The condensate water is available to the astronaut for drinking purposes following reentry and landing.

Cabin Control System

This system (fig. 11) controls cabin pressurization and temperature. Oxygen and water are supplied to the cabin control system as previously described.

A cabin relief valve is installed to automatically control the upper limit of cabin pressurization. The valve allows cabin pressure to follow ambient pressure up to 27,000 feet following launch, where the valve seals the cabin at 5.5 psi. In addition to the automatic control function, the valve incorporates a manual decompress feature. A manual control handle is located on the instrument console to provide a means of decompressing the cabin in the event of fire or buildup of toxic gases.

To provide an oxygen enriched cabin atmosphere a launch oxygen system is provided. A 1-pound 7,500-psi oxygen supply is stored in a spherical container and is metered into the cabin between 10,000 and 27,000 feet. The container is coupled with a filler valve, shutoff valve, pressure reducer, and a barometrically actuated valve. Following launch as the capsule passes 10,000 feet the barometrically controlled valve opens discharging oxygen into the cabin. This purge operation insures a minimum cabin oxygen partial pressure of 3.8 psi. The astronaut is given visual indication of this operation by a telelight on a sequence panel. A manual backup actuation lever is provided on the console to insure operation of the launch oxygen supply.

A cabin pressure regulator valve meters oxygen into the cabin to maintain the lower limit of cabin pressure. When the valve senses a decrease in cabin pressure below 5.1 psi, oxygen is metered into the cabin to maintain this minimum pressure. The valve is designed with a safety feature to prevent loss of the oxygen supply in the event of a cabin decompression. When the cabin pressure drops below 4 psi the cabin regulator valve seals, stopping oxygen flow into the cabin. In addition to these automatic controls, a manual recompress feature is incorporated to allow the astronaut to repressurize the cabin following a premeditated cabin decompression.

Cabin temperature is maintained by a water evaporator type heat exchanger, and a cabin air circulating fan similar to that previously described. Cabin gas is drawn into the heat exchanger by the fan, is cooled to approximately 45° F, and is directed into the electronic bay.

Postlanding cabin ventilation is provided by a snorkel valve system. As the capsule passes 20,000 feet following reentry, snorkel inlet and outflow valves are opened by a barometric control. Simultaneous with the opening of the snorkel valves, a shutoff valve in the pressure suit control system is closed and the emergency rate valve is opened. Ambient air is then drawn in through the snorkel inlet valve by the suit compressor, is enriched with oxygen, and is forced through the pressure suit and exits into the cabin through the exhaust port of the pressure suit regulator. The air then exits the cabin through the snorkel outflow valve. The snorkel valve system has a manual backup control on the sequence panel. The astronaut is given visual indication by a telelight of the snorkel actuation and normally would actuate the backup manual control to insure postlanding ventilation.

Instrumentation

The environmental control system instrumentation is grouped in the upper right-hand corner of the instrument panel (fig. 12). The panel provides the following environmental control system instrumentation: cabin pressure, temperature, relative humidity, and oxygen partial pressure; primary and emergency oxygen supply pressure; and carbon-dioxide partial pressure downstream of the lithium hydroxide canister in the pressure suit control system. Cabin and pressure suit system fan controls are provided on this panel. A warning light panel is installed adjacent to the environmental control system instrumentation. This panel gives the astronaut warning of major systems failures. An auditory warning signal is actuated when failures occur. The astronaut would turn off the auditory warning signal by actuating a switch located by the light, then insure that corrective action is taken. Warning lights are provided for: loss in cabin pressurization, depletion of primary oxygen supply, emergency rate mode of operation, decrease in cabin oxygen partial pressure below 3 psi, increase of carbon-dioxide partial pressure to 3 percent in the pressure suit circuit, and excessive cooling water to the suit and cabin heat exchangers. System controls are located on the left console for cabin decompression and repressurization. A telelight panel is located on the left console to give the astronaut indication of flight event sequential operation. On this panel the launch oxygen supply and snorkel operation are presented. Manual backup controls are installed adjacent to the lights. A green light indicates that the event has occurred, a red light indicates the event has not occurred. Heat exchanger water flow controls and the emergency rate valve control are located on the right console which is not shown in this figure. The instrument panel and astronaut will be photographed in flight. In addition the data from the system instrumentation will be telemetered and recorded by onboard recorders.

Continuous physiological data on the astronaut's condition in flight will be made with EKG, body temperature, and respiration rate and depth measurements. These data will be recorded by onboard recorders and will be telemetered.

SYSTEM OPERATION

Launch

The astronaut is coupled to the pressure suit control system, the helmet face visor closed, and a ground purge of the pressure suit control system is made to provide a 100-percent oxygen atmosphere. Freon is fed into the heat exchangers for ground cooling. The capsule is sealed and a leak check performed. The astronaut is maintained by the pressure suit control system with the pressure suit helmet visor closed up to and including launch.

Orbital Flight

Following launch the cabin is purged by the launch supply and cabin pressure is established at a nominal 5 psi. The astronaut may open his helmet visor in flight provided a satisfactory oxygen partial pressure exists in the cabin. This operation will be mandatory on long duration flights for feeding, etc. In the event of a cabin decompression the helmet visor is closed and the astronaut is sustained on the pressure suit control system. If the pressure suit control system fails, the astronaut may exist on the cabin atmosphere or he may resort to the emergency mode of operation. Should both the cabin pressurization system and the pressure suit control system fail, the astronaut would be maintained by the emergency rate mode of operation.

Reentry

In preparation for reentry heating the astronaut will, at a predetermined time, pre-cool the cabin and pressure suit control systems. This is accomplished by opening the heat exchanger water control valves to "full" open to allow maximum water flow into the heat exchanger. Following reentry into the earth's atmosphere the snorkel system provides ambient air for breathing and ventilation throughout the postlanding phase.

SUMMARY

An environmental control system capable of supporting one man for up to 28 hours of space flight has been developed. The system incorporates a 7,500-psi oxygen supply for breathing and pressurization, a full pressure suit and suit control system are installed as a backup to the cabin pressurization system and to control body ventilation and remove metabolic byproducts. Temperature control is provided by water evaporator type heat exchangers.

The environmental control system will be utilized in all flights of the Mercury capsule. A man simulator will be installed in the capsule to load the environmental control system on all nonbiological flights. Primates will be supported by the system in the animal phase of the project. An environmental control test capsule will be obtained for installation in an altitude chamber for astronaut training and additional test programs.

The experience gained to date with the Mercury environmental control system has been rather meager; however, it appears that a satisfactory system has been developed from more or less "off the shelf" concepts. The system has been designed with a fail safe approach, redundancy has been provided where possible, and manual backups have been incorporated for the more important automatic controls.

Before initiating designs of more advanced space flight environmental control systems, based on the Mercury system experience, it is apparent that the aeromedical field must provide realistic metabolic data for engineers to use in system design. Engineering personnel must make every effort to conserve mass by recycling. For example, the condensate water in the Mercury system could be used to supplement the coolant water and thus extend the system duration insofar as cooling is concerned. Where possible, system components should be combined as a single functioning unit to serve multipurposes.

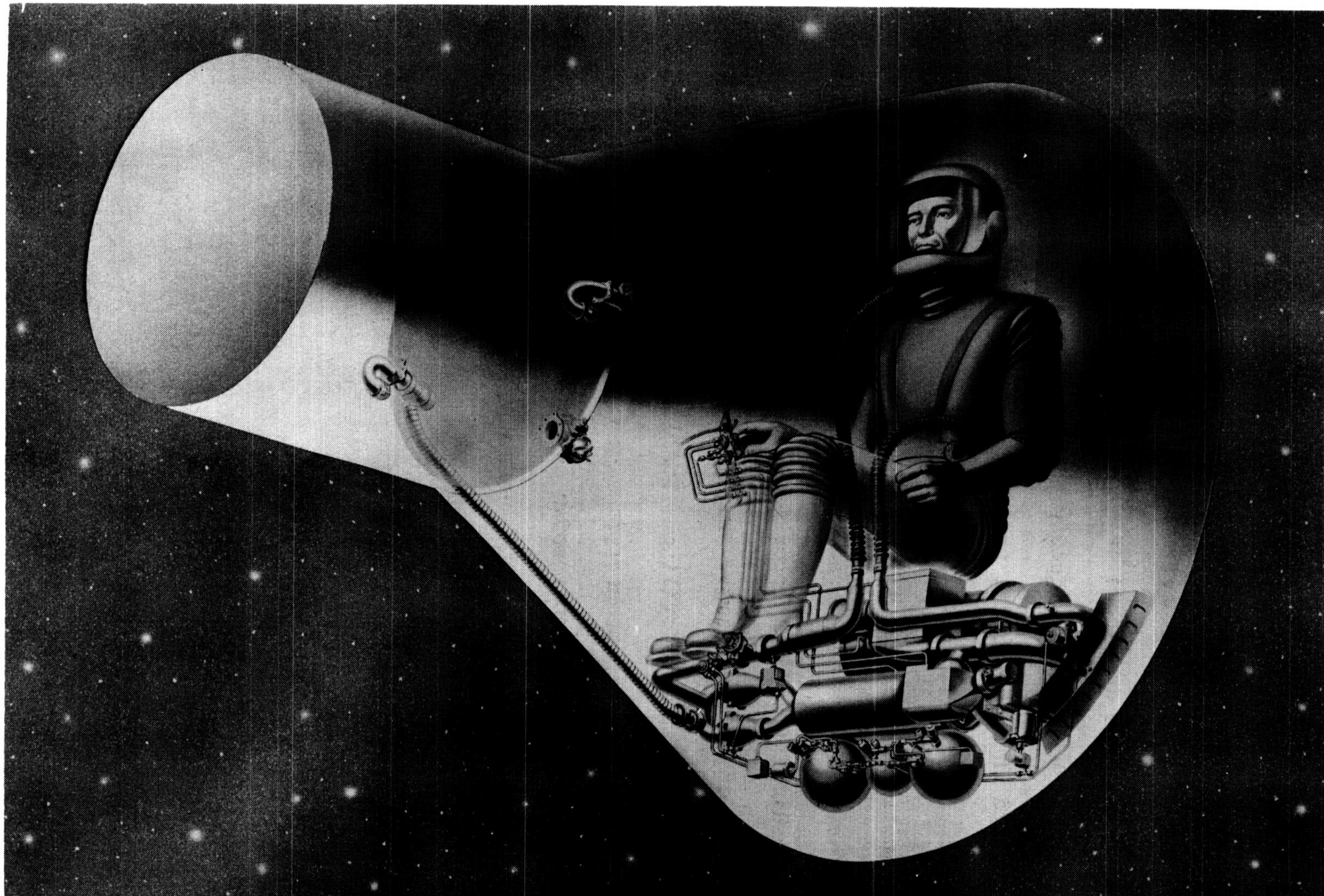

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Figure 1.- Project Mercury environmental control system.

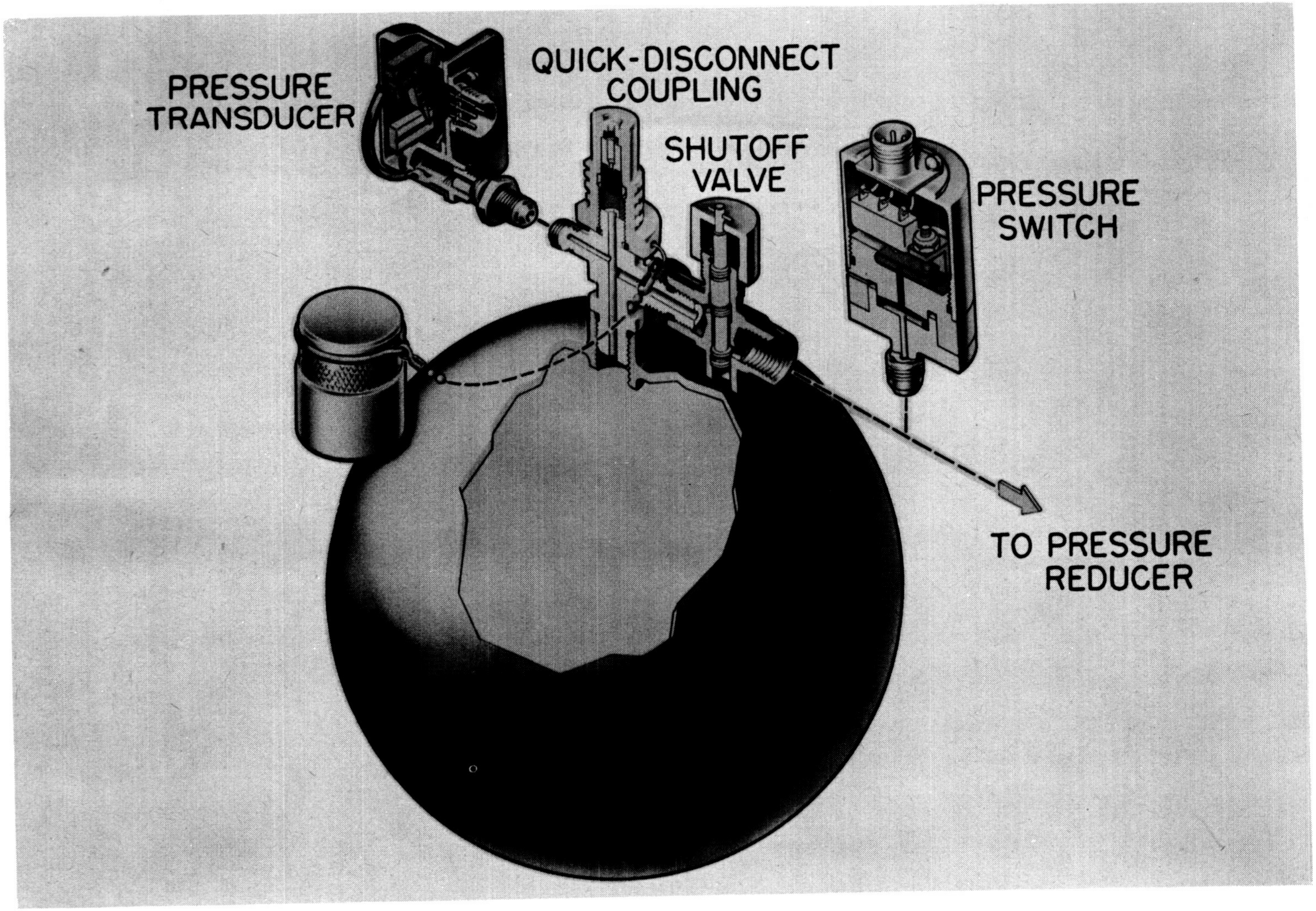

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Figure 2.- 7,500-psi gaseous oxygen supply assembly.

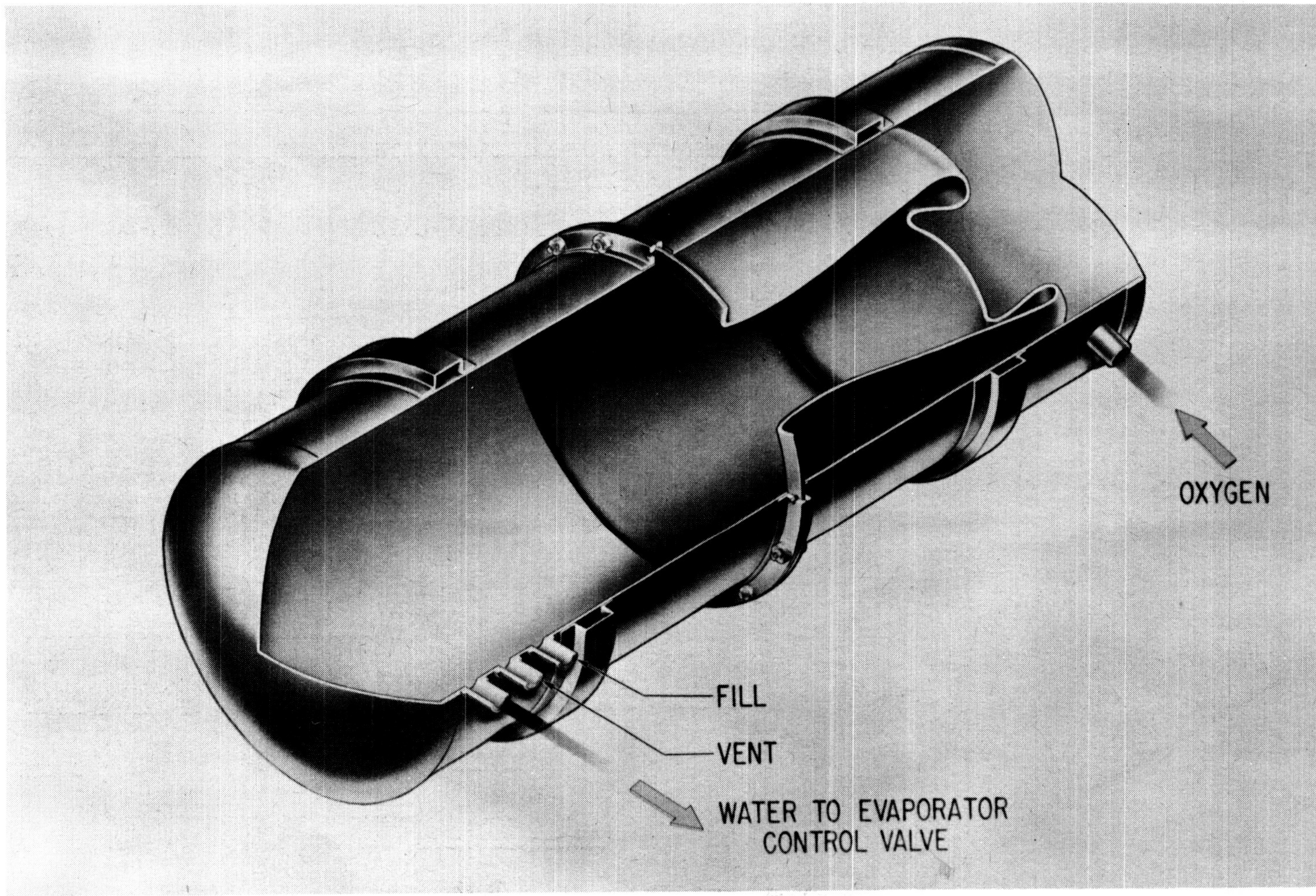

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Figure 3.- Cooling water tank.

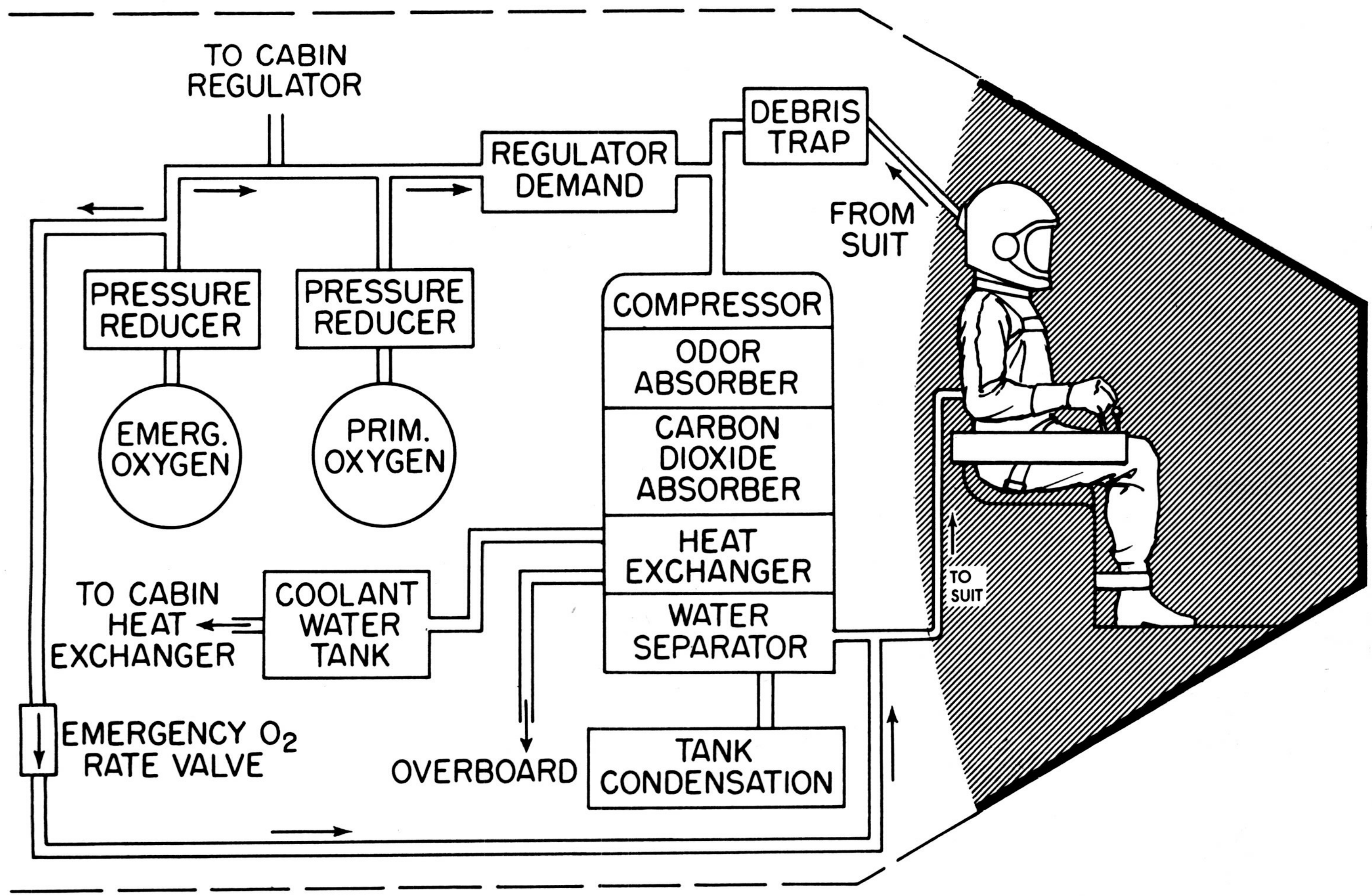

Figure 4.- Pressure suit control system.

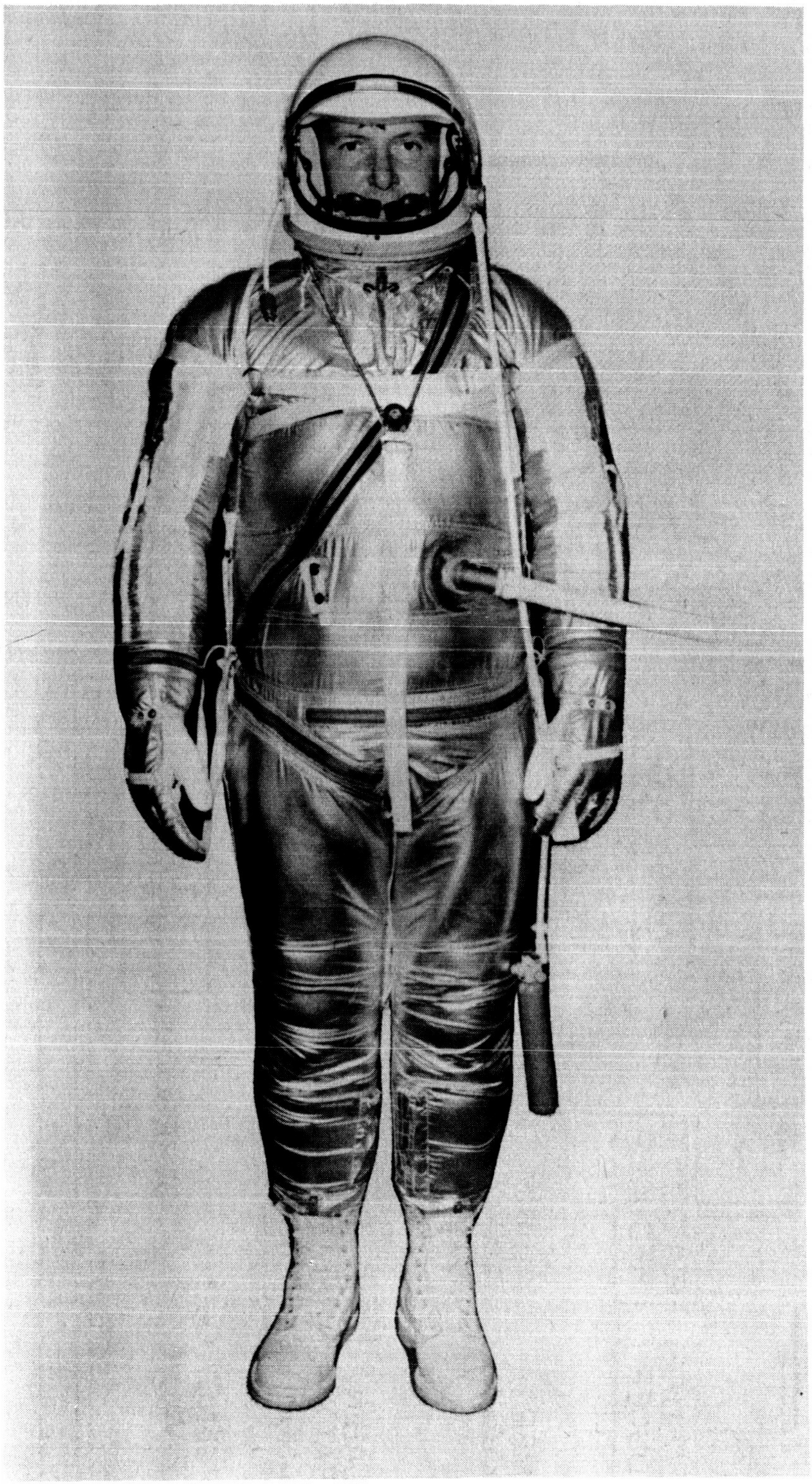

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Figure 5.- Project Mercury full pressure suit.

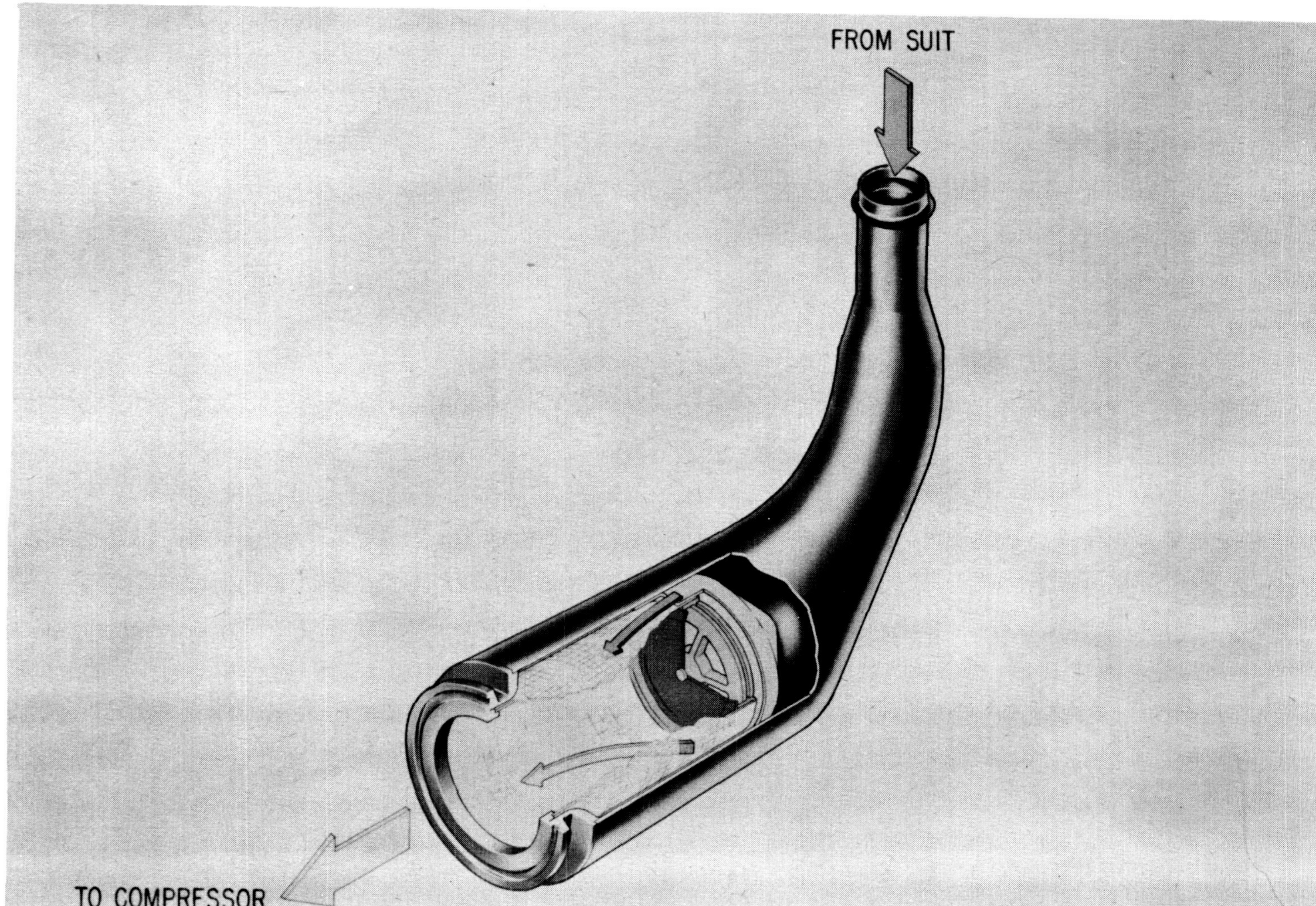

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Figure 6.- Solids trap.

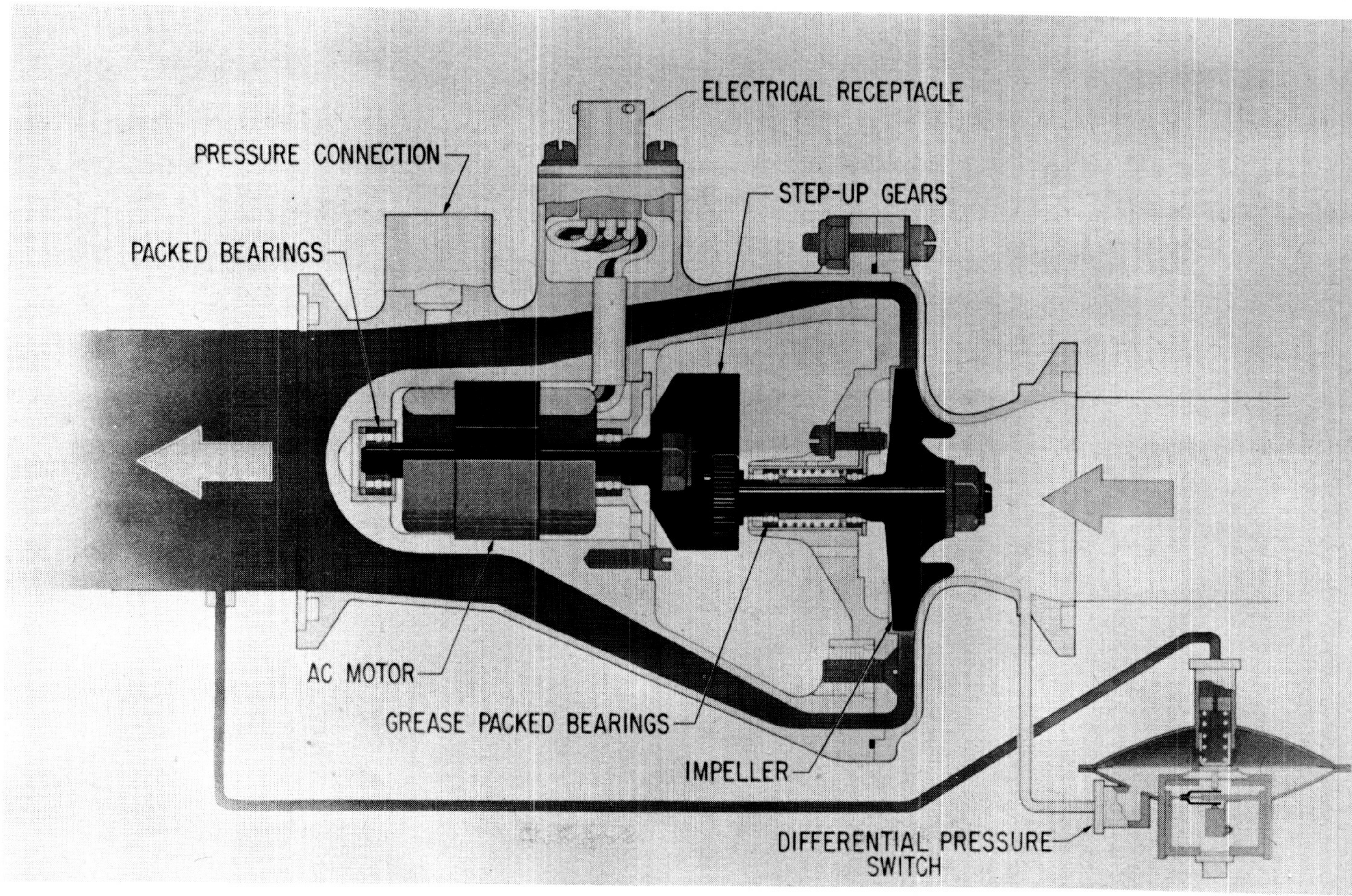

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Figure 7.- Suit circuit compressor.

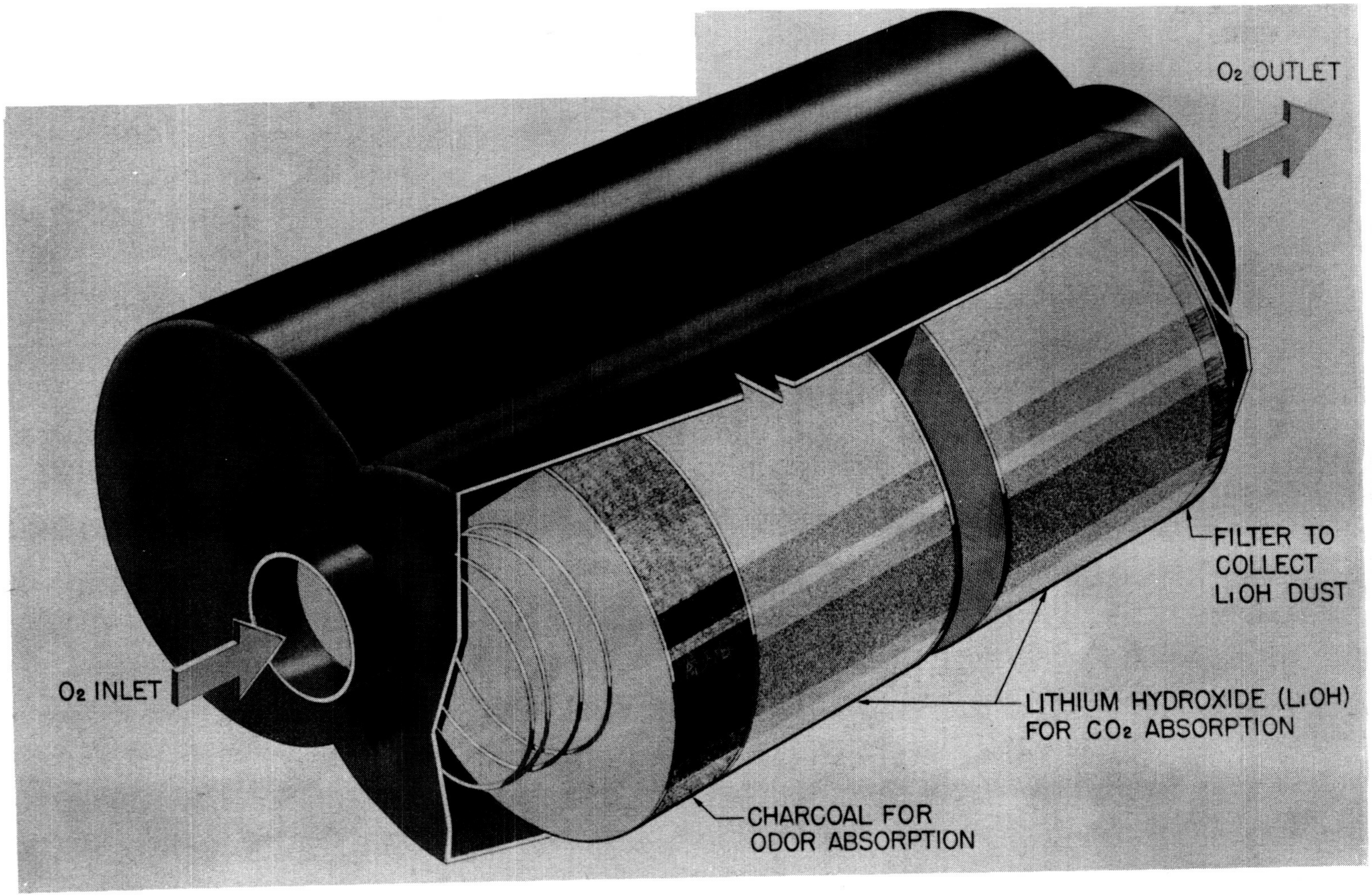

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Figure 8.- Odor and CO_2 absorber.

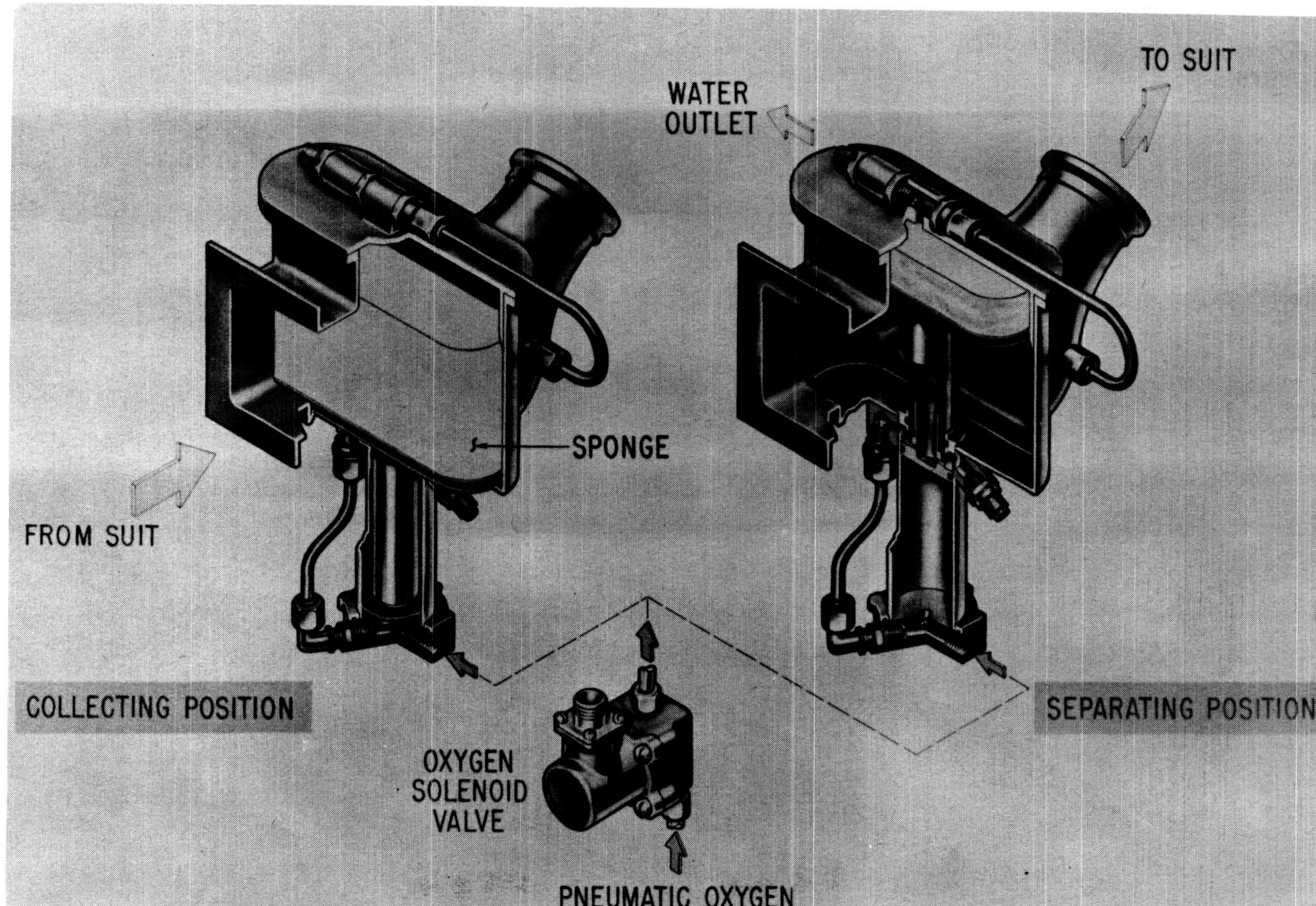

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Figure 9.- Water separator for zero gravity operation.

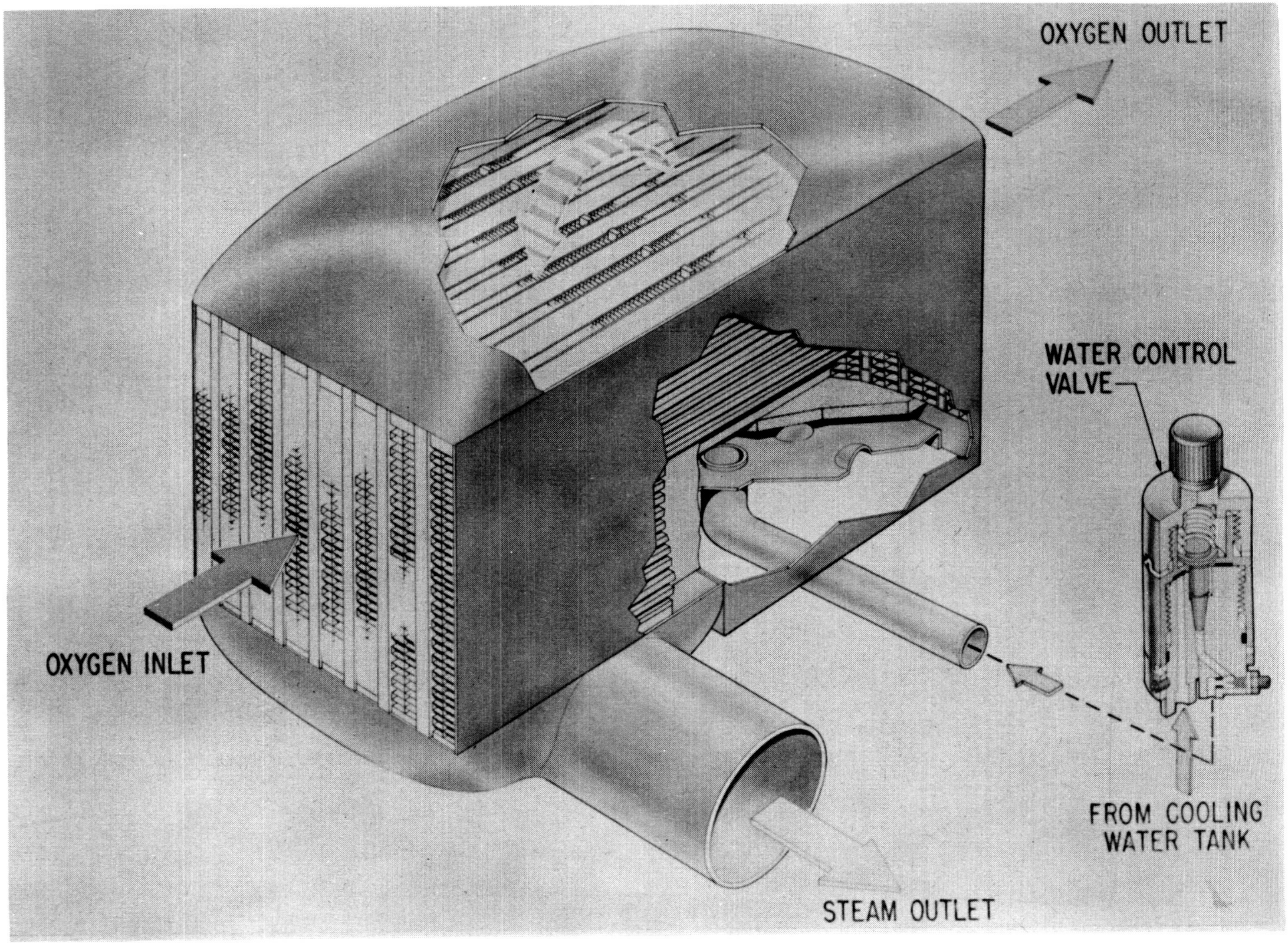

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Figure 10.- Evaporator for zero gravity and water control valve.

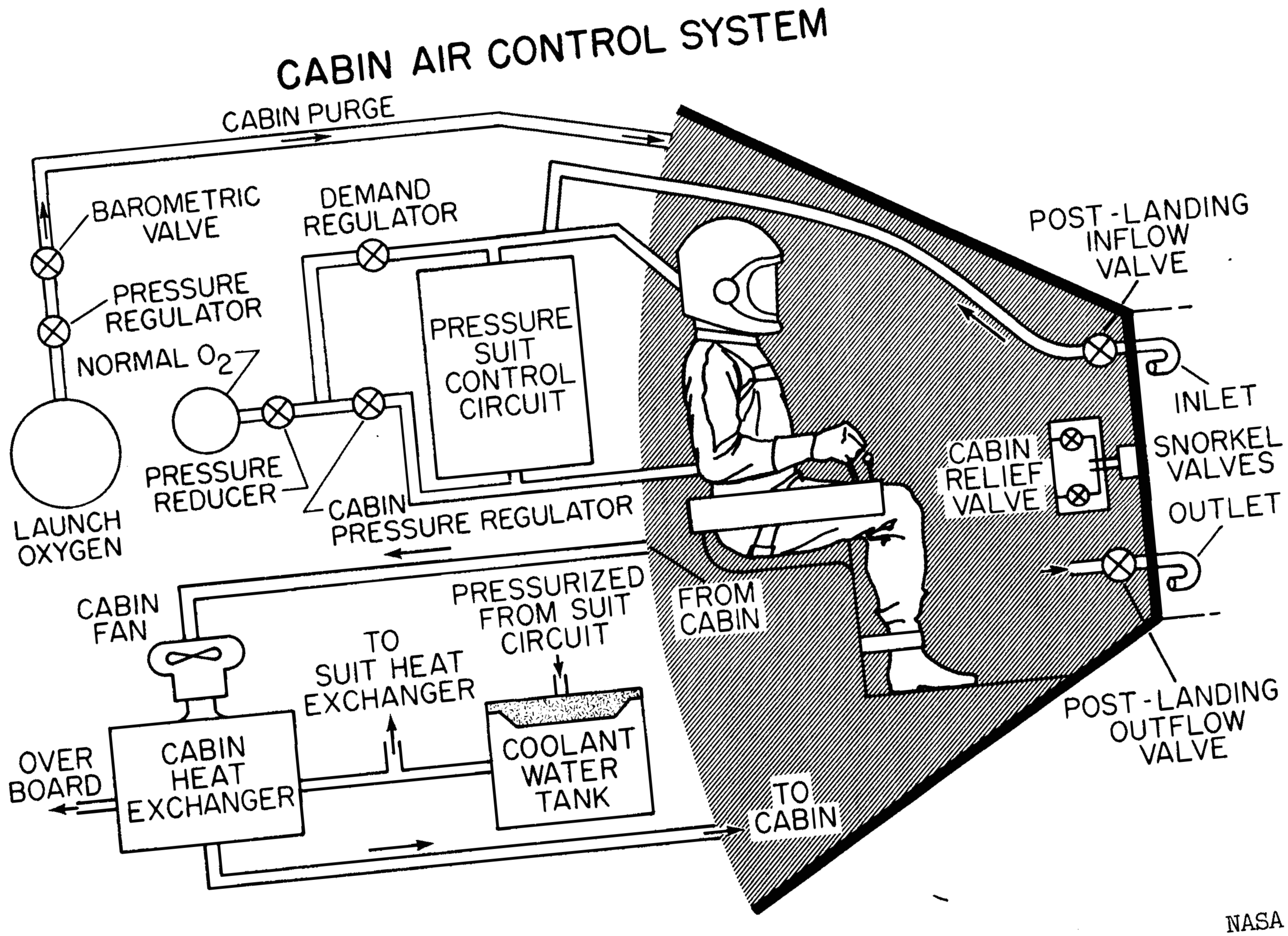

Figure 11.- Cabin air control circuit.

1.- OXYGEN AND PRESSURIZATION – 28 HOURS

2.- CABIN TEMPERATURE CONTROL

3.- CARBON DIOXIDE AND ODOR REMOVAL

4.- PRESSURE SUIT VENTILATION

5.- WEIGHTLESS AND HIGH "G" OPERATION

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Figure 12.- Project Mercury environmental control system design requirements.

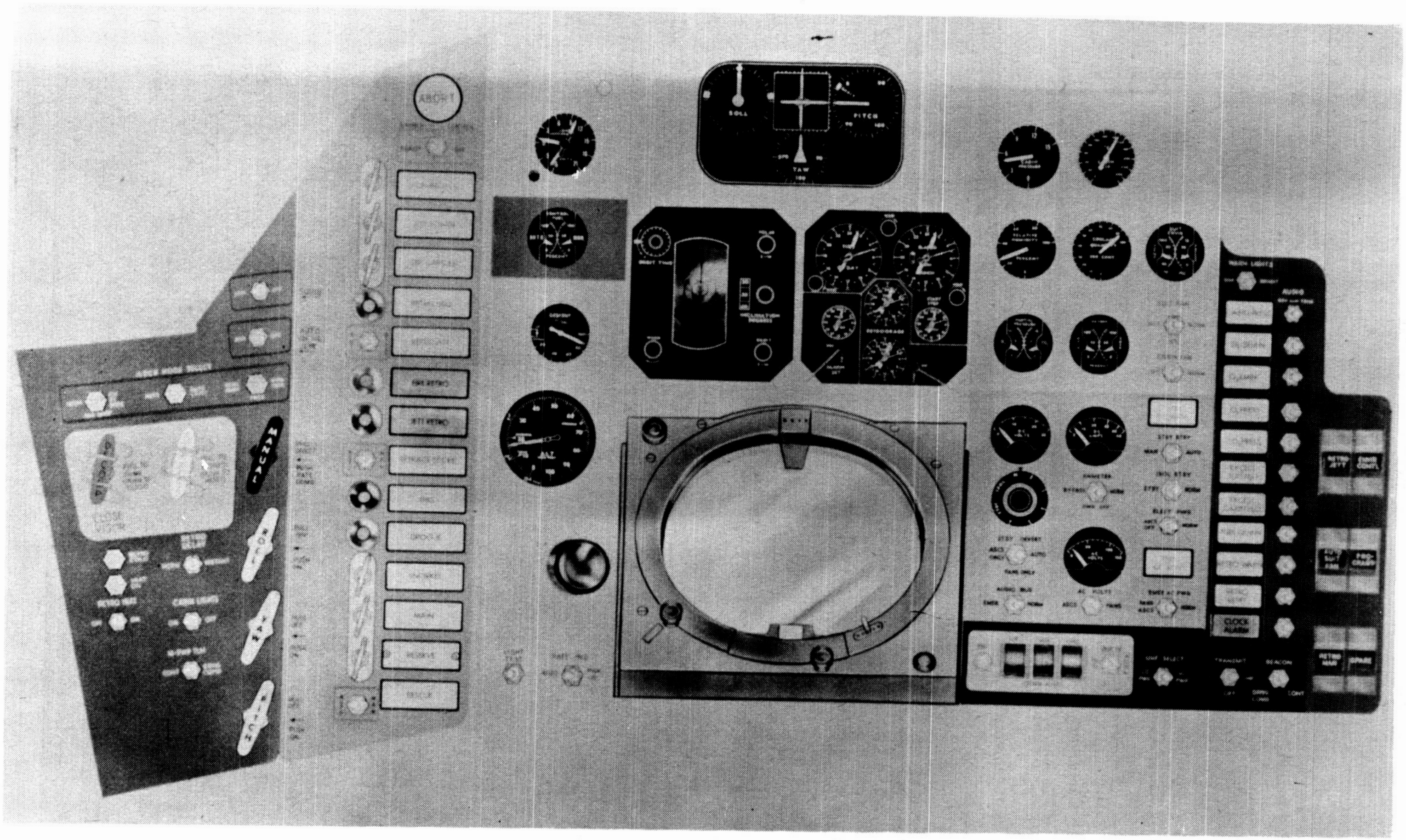

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Figure 13.- Pilot's panel.